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Battery Basics

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Initial Print Date: 12/04 Revision Date: 10/10

Subject **Page**

Battery Basics

Model: All

Production: All

OBJECTIVES

After completion of this module you will be able to:

- Explain the battery components and construction.
- Explain the chemical process of charging and discharging.
- Understand the different types of batteries.
- Describe the operation of the AGM battery used by current BMW vehicles.
- Perform battery diagnostic and charging procedures.
- Register a new battery to the vehicle.
- Check and analyze “stand by” or parasitic current draw.

Battery

Purpose of the Automotive Battery

The battery is the primary Electromotive Force (EMF) source in the automobile. In addition the battery performs the following functions:

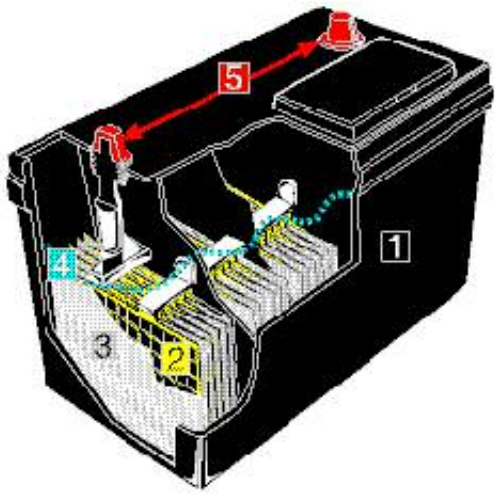
- Provides voltage and current for the starter motor.
- Provides voltage and current for the ignition during cranking.
- Supplies all electrical power when the charging system is not operating.
- Supplies the extra power necessary when the vehicle's electrical load exceeds the supply from the charging system.
- Acts as a voltage stabilizer in the electrical system. The battery evens out voltage spikes and prevents them from damaging other components in the electrical system.
- Provides power to KL30, KL15 and KLR.

The battery does not store electrical energy. It stores chemical energy that is converted to electrical energy as it discharges.

Battery Construction

The battery is made of a plastic case containing alternating plates of Lead and Lead Dioxide (or Lead Oxide) separated by insulators.

These alternating plates are connected in series to produce a voltage of 12.6 volts, or about 2.1 volts for each set of Lead and Lead Dioxide plates. The negative terminal is connected to a Lead Dioxide plate and the positive terminal to a Lead plate.



Index	Explanation
1	Plastic container.
2	Positive and negative internal plates made of lead.
3	Plate separators made of porous synthetic material.
4	Electrolyte which is a dilute solution of sulfuric acid and water better known as Battery Acid.
5	Lead terminals which are the connection point between the battery and whatever it powers.

Battery Case

Most battery cases and their covers are made of polypropylene. The case is divided into six sections or cells, shaped similar to an ice-cube tray.

The case is designed to:

- Withstand hot and cold temperature extremes.
- Resist damage caused by mechanical shock in automotive applications.
- Resist acid absorption and chemical damage.

The Grids

The grids are the supporting framework for the active material of the plates. They also conduct current to and from the active material plates.

The Plates

Plates are grids covered with a paste mixture of Lead Oxide and Sulfuric Acid and water. An expander material made of powdered sulfates is added to the paste to produce negative plates.

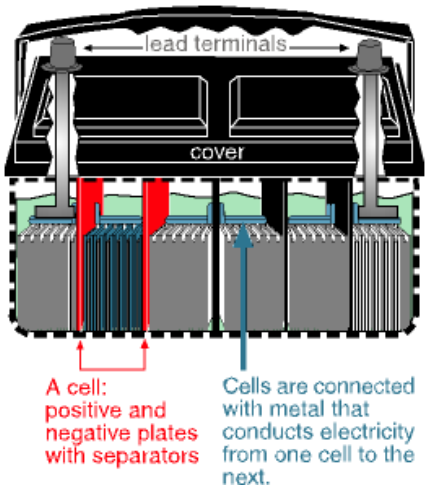
A forming charge is applied to the positive plates converting the Lead Oxide to Lead Dioxide, a highly porous material which allows the electrolyte to freely penetrate the plate.

A forming charge is also applied to the negative plates converting the Lead Oxide to Sponge Lead. The Sponge Lead allows the electrolyte to penetrate freely allowing the material beneath the plate surface to take part in the chemical reaction.

The Separators

Separators are thin sheets of electrically insulating porous material used as spacers between the plates to prevent short circuits within the cells.

Fine pores in the separators allow ionic current flow in the electrolyte between the positive and negative plates.



Elements

In the most common method of construction, a stack of alternate positive and negative plates are formed with separators between each positive and negative plate. The lugs of the negative plates are welded together as are those of the positive plates. The plate strap of each group of plates is used to connect them in series with the plate group of the next cell, or with a battery terminal.

The assembly resulting from placing one positive plate group and one negative plate group together, with separators is known as an element. There is one element per battery cell.

More or larger plates per cell will increase plate surface area and increase capacity of the battery but will not affect the voltage output.

Electrolyte

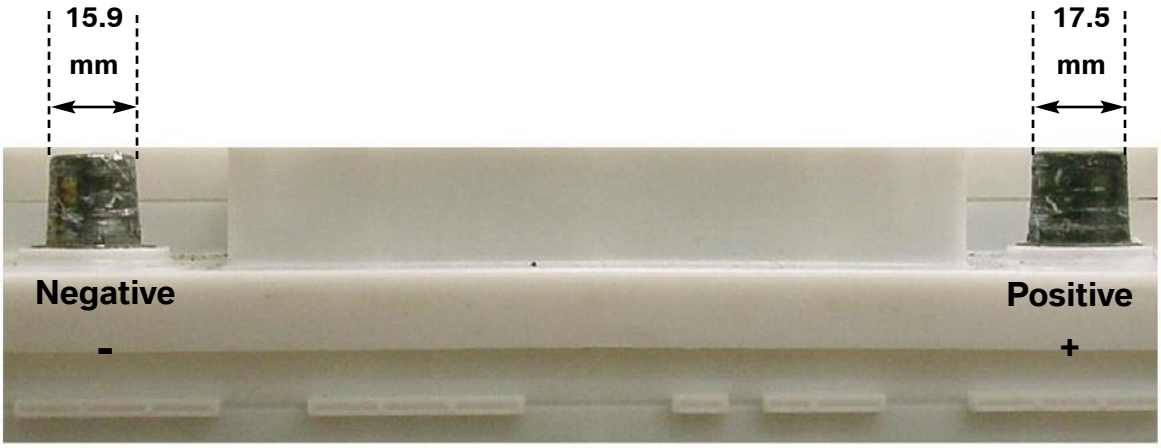
The electrolyte is a mixture of Sulfuric Acid and Water. Electrolyte consists of 35% sulfuric acid and 65% water on a fully charged normal battery.

The electrolyte is the carrier for the electric current to move between the positive and negative plates through the separators.

The Lead Terminals

BMW's use a tapered top terminal. This design uses tapered terminal posts built to industry standards so that all cable clamps will fit any battery with these posts.

The positive terminal is slightly larger than the negative to minimize the danger of installing the battery in reverse. The positive terminal is 17.5mm in diameter at the top. The negative terminal is 15.9mm at the top.



How the Battery Works

Discharging

Batteries don't store electrical energy, they store chemical energy and convert it to electrical energy during the discharging process.

Each cell of a battery contains positive and negative plates (grids). The positive plate is made of lead dioxide, the negative plate of a spongy lead. The negative plate combines with the sulfuric acid to create lead sulfate and one extra electron. The positive plate produces hydrogen ions and sulfuric acid ions (positive ions, atoms missing one electron).

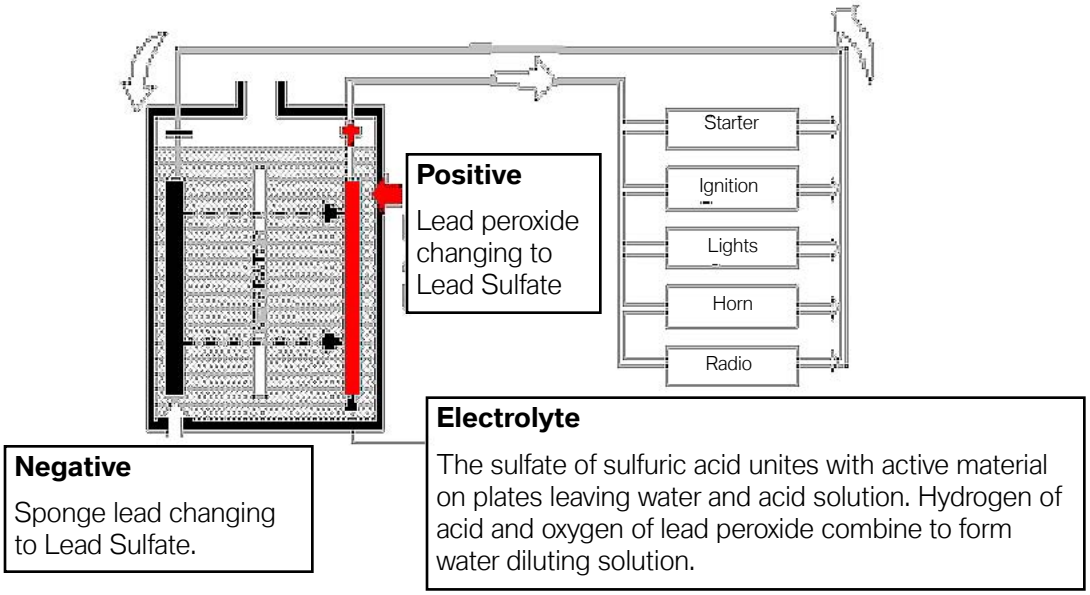
The extra electrons from the negative plate are passed from the negative battery terminal and through the electrical consumer, back to the positive battery terminal. Once back at the battery, the free electrons combine with the positive ions at the positive battery terminal producing lead sulfate and water.

It is important to remember that the system is closed. For every electron generated at the negative terminal, there is an electron consumed at the positive terminal.

As the process continues, the active materials (lead and lead dioxide plates and the electrolyte) become depleted and the reactions slow down until the battery is no longer capable of supplying electrons. At this point the battery is discharged.

The discharge process changes the ratio of sulfuric acid to water in the electrolyte, as more water is produced in the discharge process. By measuring the volume of acid in the water, the state of charge of the battery is discovered.

Discharge Process



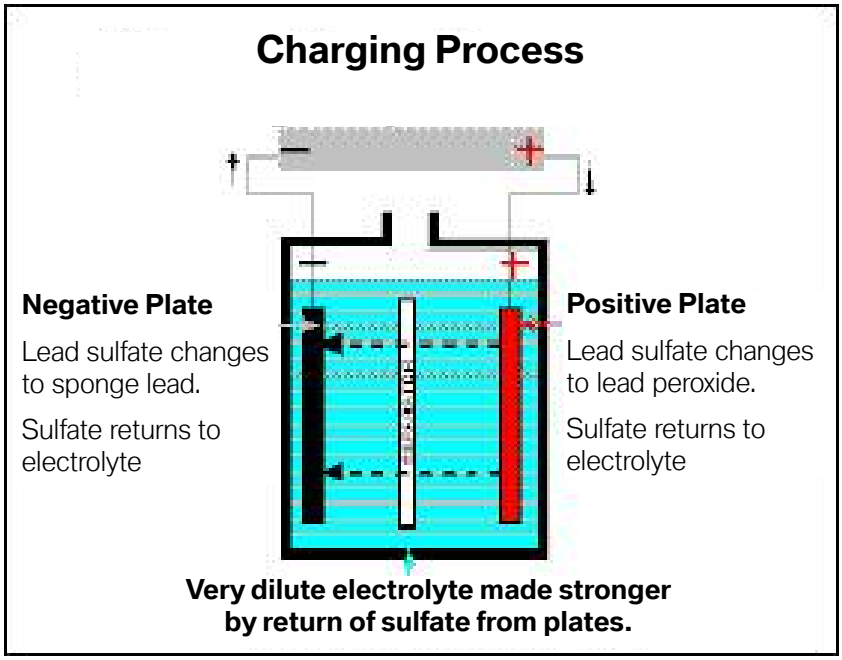
Charging

Applying voltage to the battery from an external source such as the generator or battery charger reverses the chemical action in the battery.

Reversing the chemical action in the battery, forces the free electrons at the negative terminal of the battery back into the electrolyte raising the sulfuric acid percentage. This chemical action removes the Lead sulfate that had formed on the negative plates leaving pure active material.

The electrons that were forced into the electrolyte are able to react with the lead sulfate on the positive terminal again raising the Sulfuric acid content and leaving pure active material on the positive plates.

This process enables the battery to be used over and over again.



Battery Types

There are at least four types of the Lead-acid batteries that are currently used in the Automotive Industry.

Lead-Acid Battery

The three major contributors to battery chemistry are lead, lead dioxide and sulfuric acid. Pure lead is too soft to withstand the physical abuse of mobile applications, so a strengthener is needed. About 6% antimony, a semi metallic element produced as a by-product to copper and lead ore refining, is added to strengthen the lead.

The antimony added to the grids acts as a catalyst and makes the loss of hydrogen and oxygen through outgassing worse. These batteries require frequent water replenishing.

Lead/Calcium Battery

Introduced in the 1970's Lead/Calcium batteries have Calcium added to the positive and negative grids to reduce the outgassing. These batteries were first referred to as "maintenance free". The Lead/Calcium batteries are not resistant to deep-cycling which occurs when a battery is drained to a very low voltage before being recharged. Frequent deep-cycling renders these batteries unable to sustain a charge. Lead/Calcium batteries need to be charged at higher voltage settings or they will not be recharged to full capacity.

Hybrid Battery

Hybrid batteries use a positive grid strengthened with antimony and a negative grid with calcium. The hybrid battery is more resistant to deep cycling than the lead/calcium, but still not as good as the original Lead-acid battery. Water usage is greatly reduced in the hybrid battery, although regular checking is advisable. Most cars supplied with hybrid batteries have their voltage regulators set to 14.3 volts.

Hybrid batteries were first installed in the E30 convertible (SIB 61 12 91) during the 1991 Model Year.

Absorbent Glass Mat Battery

In September 2002, the first VRLA batteries, better known as AGM batteries came into use. VRLA means valve-regulated lead acid, or a lead battery with a pressure relief valve. AGM stands for absorbent glass mat, or absorbent glass-fiber fleece.)

An AGM battery (90 Ah) was initially installed in the E46 with the M56 engine and it is currently installed on all BMW vehicles. (Refer to the AGM Battery section for further information)

Common Battery Terms

Teile-Nr. (Part No.) 61021 6 902 796

12V 55AH 480A EN 555 080 048
12V 90RC 425CCA SAE Group No . 47

fur Ersatz (for replacement):

Teile - Nr. 61 21 6 902 796 Nass (wet)

- **Ah (Amp Hour Capacity)**
  This rating is derived from discharging a fully charged battery at a constant amp draw for 20 hours @ 80°F, without the voltage of the battery falling below 10.5 volts. The constant amp draw is multiplied by the 20 hours to come up with the Amp Hour Rating.

- **CCA (Cold Cranking Performance)**
  Represents the amperage capacity a fully charged battery can deliver @ 0°F for 30 seconds before the voltage of the battery falls below 7.2 volts.

- **RC (Reserve Capacity)**
  Reserve capacity is expressed in minutes and relates to the amount of time a fully charged battery can maintain a constant draw of 25 amps @ 80°F before the voltage falls below 10.2 volts.

- **W (Watts)**
  The measurement of electrical power that the battery can deliver for a cold start. It is calculated by multiplying the starter amperage draw @ 0°F times 10 volts.

- **V (Volt)**
  Unit of measure of potential difference (Electrical pressure).

- **A (Amp)**
  The current flow in a circuit. Value is proportional to the number of electrons flowing past a point in one second.

- **Ω (Ohm)**
  The measurement of the resistance of a component or circuit to current flow.

- **Electrolyte**
  The mixture of sulfuric acid and water. 35% sulfuric acid, 65% water.

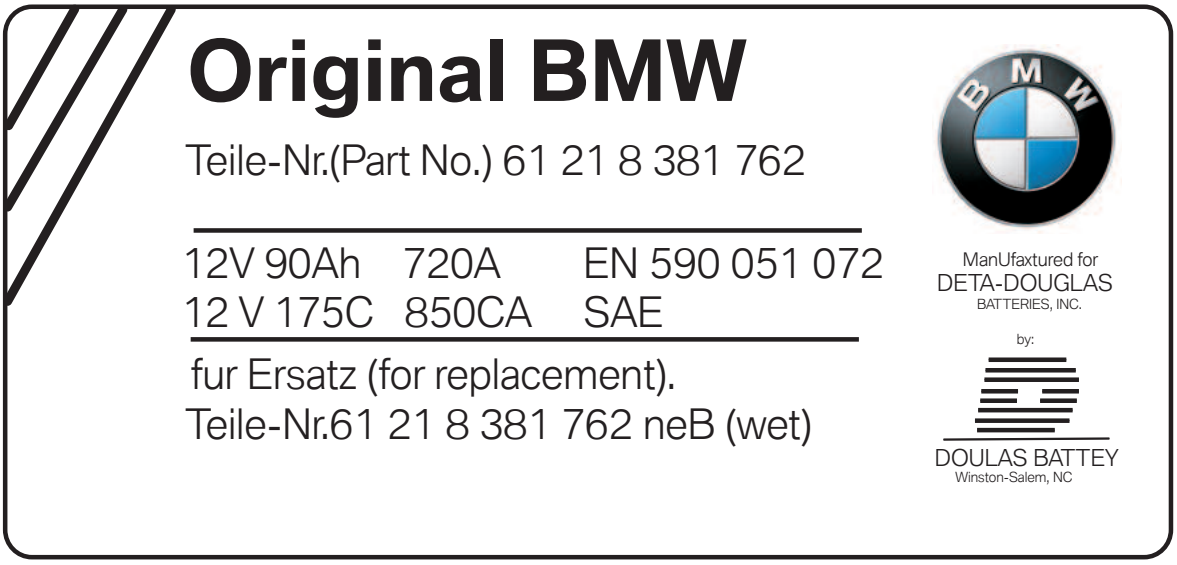
- **Specific Gravity**
  The measurement (by weight) of the volume of sulfuric acid in the electrolyte. A specific gravity of 1.275 (the specific gravity of a fully charged battery) means that the electrolyte is 1.275 times heavier than water. The specific gravity of water is 1.000.

- **Sulfate**
  Deposits formed on the plates of the battery as the electrolyte gives up its sulfuric acid.

  Excessive deep cycling of a battery can cause a hardening of this deposit and make it impossible to return sulfate to the electrolyte. A sulfated battery is one which has these hardened deposits on the plates and cannot be recharged to full capacity.

- **OCV Open Circuit Voltage**
  The measurement of the voltage of a battery across the terminals.

Notes:



Battery Testing

There are four steps to follow in testing an automotive battery:

- Inspection
- Removal of Surface Charge
- State-of-Charge Test
- Load Test

Inspection

Visual inspection is important for the detection of obvious problems:

- Loose Generator Belt
- Low Electrolyte Level
- Corroded Cable or Terminal Clamps
- Loose Hold-Down Camps or Cable Terminals
- Damaged Battery Case

Removal of Surface Charge

If the battery has just been recharged, or the car has been driven, eliminate any surface charge by one of the following methods:

- Allow the battery to sit for 2-3 hours.
- Turn the headlights on high beam for 5 minutes and wait 5 minutes after turning off.
- With battery load tester, apply a load of 1/2 the battery's CCA for 15 seconds, then wait 5 minutes.

State-of-Charge Test

Using the measured battery voltage, the state of charge can be determined. Use the table to determine the battery's state-of-charge.

Open Circuit Battery Voltage	Approximate State of Charge	Average Cell Specific Gravity
12.65 +	100%	1.265 +
12.45	75%	1.225
12.24	50%	1.190
12.06	25%	1.155
11.89	0%	1.120

Pay special attention if the DVOM measurement of OCV is equal to:

- 0 volts - Indicate an open cell.
- 10.45 - 10.65 volts - Indicates a shorted cell.

For non-sealed batteries, check both specific gravity (SG) in each cell with a temperature compensated hydrometer and battery OCV, without the engine running.

For sealed batteries (currently installed in all BMW's), measuring the battery's OCV (without the engine running) with an accurate DVOM is the only way to determine the state-of-charge.

Batteries with a built-in hydrometer measure the state-of-charge **in one cell only**. If the indicator is clear or light yellow, the battery has a low electrolyte level and should be refilled before proceeding or replaced.

A state-of-charge reading BELOW 75% using SG, voltage measurement or dark indicator in batteries with a built-in hydrometer, indicates the battery must be recharged before proceeding.

Replace the battery if one or more the following conditions are met:

- More than 0.050 difference in the specific gravity readings between the highest and lowest cell (There is a weak or dead cell).
- The battery will not recharge to 75% or greater state-of-charge or the built in hydrometer does not indicate good (green indicates 65% or better).
- DVOM reading indicates 0 volts (Open cell).
- DVOM reading indicates 10.45 - 10.65 volts (Shorted cell).

Load Test

A battery which has a state-of-charge of 75% or greater or has a "good" built-in hydrometer indication may be load tested.

With a battery load tester properly installed, load the battery for 15 seconds to one of the following:

- One-half (1/2) the CCA (Cold Cranking Amps).
- Three (3) times the AH Rating (Amp Hour Rating).

The voltage on a good battery will NOT drop below 9.7 volts during the battery load test. After the load is removed, wait 5 minutes, the battery should bounce back to 50% or greater state-of-charge. If a battery drops below 9.7 volts during the load test, does not bounce back or fails to start the engine, the battery should be replaced. Batteries which pass this test should be recharged to restore peak performance.

Load Test Conditions

- Tests assume electrolyte temperature of 80°F, 26.7°C.
- If the electrolyte temperature is above 80°F add .1 volt for every 10° up to 100°F.
- If the temperature is below 80°F subtract .1 volt for every 10° to 40°.

Battery Maintenance

Electrolyte Level

If battery electrolyte level is allowed to drop substantially, the gas volume inside the battery grows proportionately resulting in an increased amount of flammable gas mixture. Any external or internal spark may result in an oxyhydrogen explosion. Additionally the plates are no longer covered by the electrolyte and may corrode.

Note: Because BMW vehicles use a maintenance free battery, the electrolytic level cannot be topped off or maintained.

Battery Cable Connections

The top of the battery should be clean.

Check for and correct corrosion on the top of the battery and the cable connections.

Battery Charging

The purpose of charging a battery is to put back the energy that has been removed. A battery that is not properly charged will deliver sub-standard performance and display a shorter life span.

A battery should be charged only after performing a visual inspection on the battery case and the electrolyte levels. Never attempt to charge a battery with a damaged case or low electrolyte levels.

A state-of-charge test should be performed before attempting to charge a battery.

Unplug the charger or turn it off **before** disconnecting the leads at the battery.

The best charging method is to SLOWLY recharge the battery using the BMW approved battery charger. A slow charging rate allows more time for the electrolyte to penetrate the plates. Batteries that are fully discharged should be charged according to the following table.

Reserve Capacity Rating (RC)	Slow Charge	Fast Charge
80 minutes or less	15 hours @ 3 amps	2.5 hours @ 20 amps
80 - 125 minutes	21 hours @ 4 amps	3.75 hours @ 20 amps
125 - 170 minutes	22 hours @ 5 amps	5 hours @ 20 amps
170 - 250 minutes	23 hours @ 6 amps	7.5 hours @ 10 amps
above 250 minutes	24 hours @ 10 amps	6 hours @ 40 amps

Workshop Hint
Electrolyte levels may drop at a higher rate in the winter months, due to higher loads and increased utilization of electrical systems.

Workshop Hint
Many battery problems are caused by loose or corroded connections. Insure that cables are free from corrosion and tight before continuing diagnosis.

Before a battery is to be charged, it is necessary first to interrogate the fault memory in the DME/DDE in order to locate a possible load/consumer.

It is also necessary to check the battery status with the battery tester as described in the Service Information section and in bulletin 61 01 02 (804) "Battery tester".

If the battery is still discharged after a short period of use, it is necessary to carry out an external closed-circuit current measurement as described in the Service Information section and in bulletin 61 03 99 (474) "External closed-circuit current measurement".

Faulty batteries must be replaced immediately.

Before connecting the battery charger, it is also necessary to check what type of battery is installed.

Note: The battery must not be charged via the connected safety battery terminal and the intelligent battery sensor. The jump-start terminal point must be used.

Note: For further information regarding approved BMW charging equipment refer to SI B04 11 02.

Sulfated Batteries

Continuous discharging of the battery or low electrolyte levels cause crystals to form on the plates. These crystals of lead sulphate occur when a battery is discharged. The deeper the discharge the more serious the sulphation. The sulphur molecules that form the sulphate are then absent from the electrolyte, causing the electrolyte to become inefficient.

A battery relies on clean plates and strong electrolyte to both receive charging current and offer strong current discharge. A sulphated battery can do neither. Proper recharging of the battery will remove some but not all of the sulphate. Eventually the battery plates are coated with enough sulphate that it is impossible to achieve an efficient recharge.

Testing a Battery for Sulphation

A battery which fails the load test should be tested for sulphation. To test a battery for sulphation, place it on a battery charger for three minutes with the charger set on 40 amps.

After three minutes check the OCV, if the reading is greater than 15.0 volts the battery is sulphated. Batteries which indicate a sulphated condition should be recharged slowly and retested before being discarded.

Battery Replacement

Batteries determined to be defective through testing procedures should be replaced using the following guidelines.

- Reconfirm battery is actually defective and it does not need charging.
- Insure that ignition switch is in “Off” position and engine is not running.
- Disconnect negative battery terminal first.
- Place negative battery cable in a position so that it can not come in contact with battery during removal process.
- Reinstall battery hold down clamp.
- Install positive cable first.
- Recheck output of vehicle generator and balance of electrical system for other problems.
- Provide clear and concise description of the defect including cell readings, load test results and any other pertinent information which led to the battery replacement.
- Tag battery with VIN and repair order number.

Battery Failures

An analysis of batteries replaced under warranty shows that many claims could have been avoided had the batteries been maintained in a full state of charge.

Batteries must be maintained at all times when vehicles are at a retailer whether they are new cars, used cars, in storage (back lot), on display, or customer cars in for maintenance or repairs.

Batteries replaced due to lack of maintenance will not be covered by warranty.

Most common causes of premature battery failures:

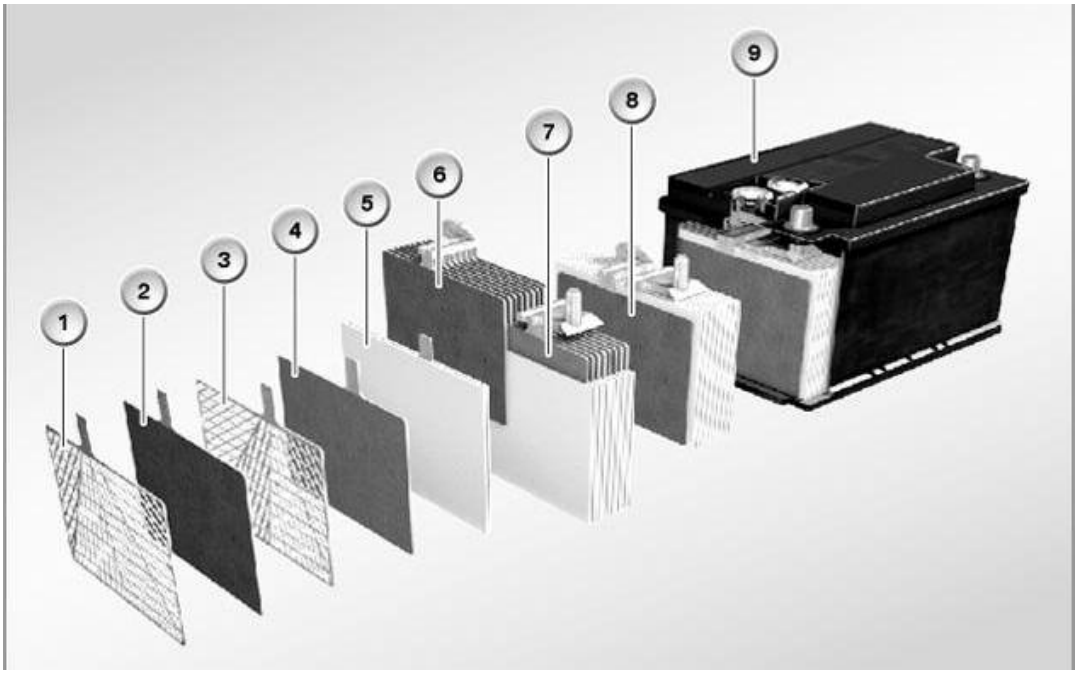
- Failure to maintain proper state of charge
- Loss of electrolyte due to overcharging or excessive heat
- Deep discharging (Leaving lights on or other parasitic draws)
- Undercharging of battery
- Vibration (Loose battery hold down clamp)
- Using tap water (instead of distilled water)
- Corrosion
- Freezing.

Absorbent Glass Mat Battery

The continuously increasing energy requirements of modern vehicle electrical systems, demands ever more efficient battery solutions. A modern luxury vehicle has many components that have to be provided with electrical current. In addition, many safety, environmental and comfort features became increasingly a part of the standard equipment such as ABS (anti-lock brake system), DSC (dynamic stability control), EPS (electric power steering), heated catalytic converters, electronically controlled suspension, air conditioning and navigation systems. Current consumption is considerable even when the vehicle is not in use.

AGM batteries are more expensive to produce, however this extra cost is offset by the following benefits:

- Much longer service life Improved starting reliability at low temperatures
- Reliable starting of engines with high starting current requirements
- 100% maintenance-free
- Low risk in the event of an accident (reduced environmental risk)



Index	Explanation	Index	Explanation
1	Positive grille with silver alloy	6	Set of positive plates
2	Positive plate	7	Set of negative plates
3	Negative grille	8	Block of plates
4	Negative plate	9	Block box with base strips
5	Separator made of glass-fiber fleece		

Construction

AGM batteries differ from conventional lead-calcium batteries in the following points:

- Larger plates:

  Larger plates allow a power density some 25% greater.

- Glass-fiber-fleece separators:

  This enables a cycle consistency up to 3 times greater to be achieved.
  This improves cold-starting ability, current consumption and service life.

- Airtight housing with pressure relief valve:
- The inspection plugs are sealed and cannot be opened.
- Acid bound in grass-fiber fleece:

  In contrast to conventional lead-calcium batteries, the sulfuric acid in a battery with fleece technology is not held as a liquid in the battery housing, but rather it is completely bound (100%) in the glass-fiber fleece (separators). This gives increased security against the acid escaping and thus reduces the environmental risk. For this reason, no acid can escape if the battery housing is damaged. In addition, the AGM battery is sealed to be airtight. This is possible because the gases are converted back into water by the permeability of the separators.

How it Works

AGM batteries differ from conventional lead-calcium batteries in their environmental compatibility and their retention of gases during charging.

When a vehicle battery is charged, the electrolysis process emits the gases oxygen and hydrogen.

- In a conventional lead-calcium battery, these two gases are released into the atmosphere.
- In an AGM battery, the two gases are converted back into water: The oxygen created at the positive electrode during charging moves through the permeable glass-fiber fleece to the negative electrode, where it reacts with the hydrogen ions that are brought in with the electrolyte, to create water (oxygen cycle). In this manner, the gases, and thus the electrolyte, is not lost.

Only when the gas production is excessive, that is when too much pressure is generated (20 to 200 mbar), does the pressure-relief valve open, thereby allowing gas to escape while also preventing entry of atmospheric oxygen. Because the pressure in the battery is regulated by a valve, the AGM battery is also known as the VRLA battery (valve-regulated lead acid).

Service Instructions for AGM Batteries

When handling AGM batteries, certain special factors must be taken into consideration with regard to battery renewal and installation location.

Charging

When charging batteries in the "stand alone" mode, the maximum charge voltage of 14.8 volts must not be exceeded. Even briefly charging an AGM battery with a charge voltage of more than 14.8 volts (voltages usually used in rapid charge programs) will damage the battery.

WARNING!!! **Do not charge AGM batteries with 14.8 volts!**
Do not use rapid charging programs!

Installation Location

WARNING!!! **Do not install AGM batteries in the engine compartment!**

Because of large temperature variations, AGM batteries must not be installed in the engine compartment. This would result in a significant reduction in the service life of the battery.

CAUTION!!! **Do not open AGM batteries**

On no account should AGM batteries be opened, as oxygen from the atmosphere would cause the battery to lose its chemical balance and cause it to fail.

Battery Testing

For all models up to F10, we should use the Midtronics tester, **NOT** a VAT40 or equivalent to test the battery.

For F10 and later, a battery test is built into the vehicle, and is accessed using ISTA.

A battery may only be replaced on F10 when identified as faulty using ISTA (the test plan returns a diag. Code for the replacement).

Note: For all models up to F10, we should use the Midtronics tester, NOT a VAT40 or equivalent to test the battery. For F10 and later, a battery test is built into the vehicle, and is accessed using ISTA.

A battery may only be replaced on F10 when identified as faulty using ISTA (the test plan returns a Diagnostic Code for the replacement)

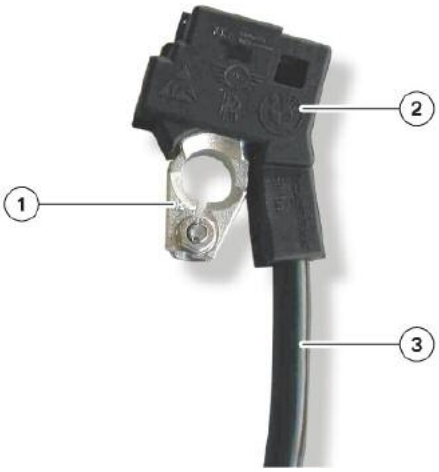
Battery Replacement

An AGM battery, when installed as original equipment, must always be replaced with an AGM battery.

In special cases, where a customer's driving profile (e.g. short distance driving), results in a discharged battery, the AGM battery is a recommended replacement. Note that replacement batteries resulting from a customer's driving profile cannot be claimed under warranty.

IBS: Intelligent Battery Sensor

The IBS was first introduced with the E60 and later was gradually installed in most current models. It is a mechatronic, intelligent battery sensor with its own microprocessor. The microprocessor is an element of the electronics module. The electronics module is used to detect the voltage, the current flowing and the temperature of the battery.



Index	Explanation
1	Negative battery terminal
2	Intelligent battery sensor
3	Negative battery cable

The following components are fitted in the electronics module:

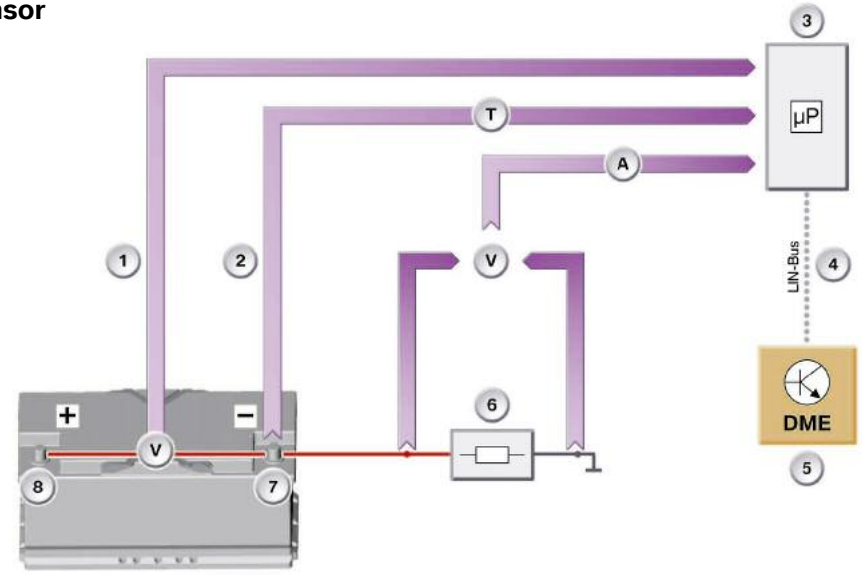
- a shunt (resistor for current measurement)
- a temperature sensor
- evaluation electronics on a board

The IBS continuously measures the following values on the battery:

- Terminal voltage
- Charge current
- Discharge current
- Battery temperature

For data transfer, the IBS is connected to the DME (Digital Motor Electronics) or DDE (Digital Diesel Electronics) via a Local Interconnect Network bus (LIN bus) or BSD on earlier vehicles.

F10 IBS Sensor



Index	Explanation	Index	Explanation
1	Measurement of the battery voltage between the positive battery terminal and negative battery terminal	5	Digital Motor Electronics (DME) or Digital Diesel Electronics (DDE)
2	Temperature measurement of the battery (T)	6	Current measurement (A) [indirect, via the proportionally voltage drop (V) at the measuring resistor (shunt)]
3	Microprocessor (µC) in the intelligent battery sensor (IBS)	7	Negative battery terminal
4	Local Interconnect Network bus (LIN bus) for transmission of the values to the DME or DDE.	8	Positive battery terminal

Determining the Battery State of Charge

Battery state of charge

The APM with the intelligent battery sensor determines the battery state of charge while the vehicle is being driven and when the vehicle is at a standstill on the basis of measurement data:

- Vehicle being driven:

  Balancing the charge and discharge current of the battery.

  Calculation of the current characteristics on engine start to ascertain the battery condition.

  While the vehicle is being driven, the IBS transfers the data across the LIN bus bit to the engine control unit (DME/DDE). The software in the IBS controls the communication with the higher-level engine control unit (DME/DDE).

- Vehicle at a standstill

  When the vehicle is at a standstill, the measured values (open-circuit voltage measurement) are queried in cycles to detect energy losses. The measured values are entered in the IBS in the memory and transferred to the DME/DDE after restarting the engine.

Note: Refer to the Power Supply section in the ST401 Body Electronics II training material for further information regarding the IBS (Intelligent Battery Sensor) and BST (Battery Safety Terminal).

For the history of the battery state of charge, the following values are stored in the DME/DDE:

- Battery state of charge of the last 5 days.
- Charge status histogram showing periods in the ranges 0 - 20%, 20 - 40%, 40 - 60%, 60 - 80% and 80 - 100%. The charge status histogram is reset in the following cases: programming the DME/DDE or registering a battery replacement.

Evaluation of the battery state of charge.

If the rest phase is not sufficiently long or if there is a standby current violation, the battery state of charge cannot be determined correctly: the state of charge is implausible.

Startability limit

The APM calculates a lower and an upper startability limit for the battery:

- The lower startability limit corresponds to the minimum charge state of the battery so that the vehicle can still be started.
- To counteract discharge down to the lower startability limit, a certain charge volume is kept as a reserve. To achieve this, the upper startability limit is calculated. This value is used e.g. as the limit value for the requests for deactivation of terminal 30B when auxiliary consumer units are active.

The startability limit is calculated by evaluating the following measured variables:

- Average battery temperature with vehicle parked.
- Ambient temperature of the last journey.
- Current state of charge.
- Voltage dip of the last engine start (trend for aging of the battery).

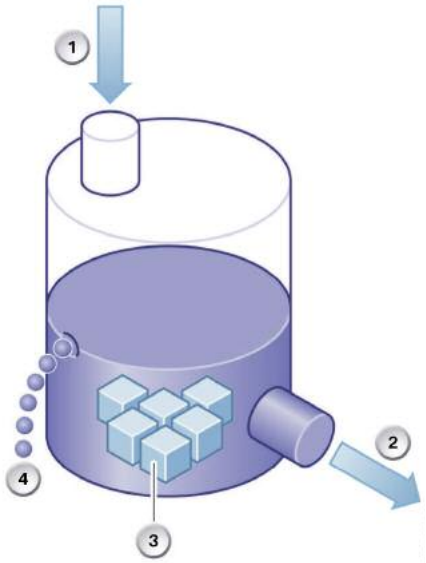
Note: For all models up to F10, we should use the Midtronics tester, NOT a VAT40 or equivalent. For F10 and later vehicles, a battery test is built into the vehicle (through the IBS), and is accessed using ISTA.

Note: A battery may only be replaced on F10 when identified as faulty using ISTA (the test plan returns a Diagnostic Code for the replacement)

Determining the Battery Condition

Battery condition

The battery condition cannot be determined based on the battery state of charge alone. All batteries are subject to natural wear due to the natural aging process. The chemical reactions in the battery, consisting of the charge cycles with battery charging and discharging, mean that deposits form in the battery, preventing the battery from reaching full capacity.



Index	Explanation
1	Battery Charge
2	Battery Discharge
3	Aging/deposits
4	Self-discharging

The enhanced intelligent battery sensor as of F10 enables better detection of the battery condition by:

- Detection of defective battery cells
- Calculation of the remaining battery capacity

Each total discharge results in a loss of battery capacity: The longer the battery remains completely discharged, the greater the loss of battery capacity. The batteries installed at BMW can withstand several short total discharges or up to two long total discharges, however, when they are fully recharged with a constant charging voltage of 14.8 V after the total discharge.

Fault entry: Battery very aged or defective

If monitoring of the battery condition identifies an aged or defective battery, a fault entry is registered in the engine management fault memory. The fault entry can not be deleted until the battery has been replaced and the new battery has been registered.

IBS Service Information

Charging and trickle charging of the battery

The battery may only be charged using the chargers approved by BMW at a constant charging voltage of 14.8 V.If possible, the battery temperature during charging should be between 15 °C and 25 °C. Under these conditions, the battery is adequate charged if the charge current has fallen below 2.5 A. If the charging process is carried out at low temperatures, it is only to be terminated after the charge current falls short of 1.5 A. If the battery is charged when fitted, the charging process must take place via the jump start terminal point. This is the only way to ensure that the charging process is detected correctly by the vehicle electronics on vehicles with an intelligent battery sensor (IBS). If the battery is charged directly at the battery terminals, misinterpretations of the battery condition and, under certain circumstances, unwanted Check Control messages or fault code memory entries can occur. The cigarette lighter is supplied with voltage by the front power distribution box via switched terminal 30B. After terminal 30B off, the relay de-energizes. This means that a trickle charger connected at the cigarette lighter would be disconnected from the battery. Only charge the battery via the jump start terminal point.

Replacing the IBS

The vehicle with the new IBS must be placed in the rest state for at least 3 hours: Only then can the new IBS determine the battery condition. The Check Control message 'battery severely depleted' is then no longer displayed if the battery is adequately charged and the correct battery state of charge can be displayed.

Register battery replacement

After fitting a new battery, the service function 'Register battery replacement' should be run. The battery change has to be registered in order to tell the power management system that a new battery has been fitted to the vehicle. If the battery change is not registered, the power management will not function properly, with the result that Check Control messages may be displayed and functions limited by individual electrical consumers being switched off or having their power consumption reduced, for example.

Service Information

Dead Battery Diagnosis

The electrical system of BMW vehicles has been subject to an ongoing development process over the last few years. This has led to increased demands being placed on the battery.

A dead battery can have various causes, most of which do not concern the battery itself. A failed battery is often the symptom and not the cause. A fully serviceable battery fails because it becomes discharged.

For this reason, replacing the battery is not usually a permanent repair. The cause of the dead battery must be analyzed in order to guarantee a proper repair.

Only use the latest diagnostic software when diagnosing dead battery complaints.

To correctly troubleshot a dead battery in current BMW vehicles (E65, E66 from 3/2004 vehicle production and all other vehicles equipped with MOST-bus) the “Energy Diagnosis” test plan must be performed on all dead battery complaints. (Refer to SI B61 13 05)

At the conclusion of the "Energy Diagnosis" test plan, a diagnostic code will be generated. Certain Energy Diagnosis test plan results ("Exhaustive Battery" charge or "Terminal 30g-f shutdown due to start capability limit", for example) are for informational purposes only, and would not display a diagnostic code. In these cases, the most likely cause is a faulty battery.

This code (if displayed in the test plan) must be included in the "Comments" section when submitting the warranty claim.

Note: Failure to quote the diagnostic code in the comments of the warranty claim may result in a delay in processing or refusal of the warranty claim.

The two exceptions to the rule are:

- Battery damage and leakage
- Use of mobile service and battery replacement to restore customer drivability as soon as possible. In the case of a battery replacement during a roadside repair, a subsequent service appointment needs to be scheduled for the customer, in order to perform an energy diagnosis to locate and address the cause of the battery failure, as well as to register the replacement battery.

Performing the Energy Diagnosis Test Plan

Fault Analysis (Energy Diagnosis)

There are currently two paths to access the energy diagnosis test plan:

- If a power management fault is stored, ISTA will select the energy diagnosis test plan automatically.
- The test plan can also be selected manually:
  "Function structure>Body>Power supply>Energy Diagnosis".

Note: The vehicle must have a discharged battery before Energy Diagnosis can be performed. Also, fault codes must not be deleted.

Once the test plan has finished, the "Most Likely Causes" are automatically displayed if any are calculated by the test plan. Finish the test plan by processing all the "Most Likely Causes", starting from [1]. If no "Most Likely Causes" are calculated, the results screen will be displayed: "Most Likely Cause (0)".

Possible "Most Likely Causes" are:

Vehicle fault

- Battery fault/alternator fault
- Vehicle is not entering sleep mode
- Vehicle is constantly awoken from sleep mode
- Closed-circuit current is too high
- Exhaustive battery charge (for information only)
- Terminal 30g-f shutdown due to start capability limit (for information only)
- Undetermined

Operating fault

If one of the causes shown below is displayed in "Most Likely Causes", this is not considered a factory defect and a warranty claim should not be submitted, even though a diagnostic code is generated at the end of the test plan.

- Lights/hazard warning lamps left on for too long
- Terminal R/15 left on for too long

Except for the vehicles listed below, the fault is set when the engine is off and terminal 15/R is left on for more than 30 minutes; and the power supply drops below 11.5 volts for at least 2 minutes. The amount of time that terminal 15/R is left on is accurate.

For the following vehicles, this fault is not reliable and should not be considered a customer error:

- E65 and E66 (7 Series)
- E90, E91, and E92 (3 Series) prior to 3/07
- E60 and E61 (5 Series), vehicle integration level prior to E060-07-09-500
- E63 and E64 (6 Series), vehicle integration level prior to E060-07-09-500
- E70 (X5) prior to 3/07
- Unfavorable driving profile (e.g., extremely short distances)
- Vehicle parked for too long

Note: A functional description of Energy Diagnosis and terminal control, together with troubleshooting information, can be found in the Energy Diagnosis test module.

Closed circuit current measurement

Refer to the Closed Circuit Current Measurement section in this training material, for the procedure and troubleshooting hints and to ISTA functional description for further information.

Note: For further information regarding Closed-circuit Current Measurement refer to SI B61 08 00 available in ISTA.

Checking the charging system

Refer to SI B04 25 02 for information on how to test the charging system.

Checking the battery condition

Refer to SI B61 11 09 for information on how to test the battery. For further information refer to the ISTA functional description.

Use the following path:

Function structure>Body>Power supply>Alternator.

New battery registration

Registration of the new battery is necessary, using the ISTA service function. If the new battery is not registered, erroneous messages (check control) may appear.

Use the following path the register the new battery and follow the test plan instructions:

"Service function>Body>Power supply>Battery>Register battery change".

If a new battery is installed, the "Energy Diagnosis" test plan should be completed prior to registering the new battery. When the battery is registered, the stored energy history is deleted. This may cause the vehicle to return if the root cause of the dead battery is not determined.

Recharging the battery

Refer to the battery Charging section of this training material or to **SI B61 11 09** for more information on how to recharge the battery.

Battery Charging and Testing Procedure

The following proper battery testing and charging procedures are necessary to fulfill the requirements of the warranty as well as meeting customer expectations.

Vehicles with a discharged battery must have their batteries charged and tested prior to proceeding with further diagnostics.

Battery Charging Procedure

1. As described in bulletin SI B04 27 06, be certain that the charging voltage on approved BMW chargers has been set to 14.8 volts. Failure to set the charge rate to 14.8 volts will result in the charger switching to FC (floating charge) before the battery is adequately charged.
2. Be sure to refer to the Deutronic DBL-430/DBL-800 or V&H MultiCharger 750 manuals for proper charger setup procedures. Additionally on Deutronic chargers refer to attachments "DBL-430 Settings" and "DBL-800 Settings" for the correct default settings to use.

   When using any Deutronic battery charger, be sure that the charging amperage has been set at 15%-20% above the amp hour rating of the battery. Since the Deutronic DBL-430 is only adjustable in amperage increments of 10, it may be necessary to round up to the next higher amperage setting. Failure to do so will result in an undercharged battery. For a 90Ah battery, set to 110A and for 110Ah, set to 130A.

   The Deutronic DBL-800 charger, as well as the V&H MultiCharger 750, is self-calibrating; however, voltage and amperage can be manually set in the service menu and should be checked and adjusted as necessary, prior to charging.
3. If the vehicle is equipped with an IBS (Intelligent Battery Sensor), be sure to charge the battery from the service port or disconnect the battery from the vehicle. DO NOT connect the charger directly to the IBS.
4. A fully charged battery is indicated on the Deutronics chargers by a green LED and the letters "FC" for "Floating Charge" being visible in the LCD display. The V&H MultiCharger 750 will display "Battery Full" in the LCD display.

Midtronics Battery Testing Procedure

1. All battery tests must be performed directly at the battery.
2. For in-vehicle testing, all electronic loads must be off, as a high-current draw in the period before sleep mode may adversely affect the result.
3. Both Midtronics tester clamps must be firmly attached to the appropriate battery terminals which have been cleaned with a wire brush. Follow the menu prompts.

4. Select "IN-VEHICLE" or "OUT-OF-VEHICLE" (as appropriate).
5. Select the CCA rating from the vehicle battery label.
6. If the warning "SYSTEM NOISE" is displayed, be sure all electrical loads such as open doors, interior lighting or active systems are turned off. In rare cases, it is possible for an active BUS line to produce sufficient electrical noise to hamper testing. In such instances, the BUS must be allowed to enter sleep mode before proceeding, or the vehicle may be placed in sleep mode using the diagnostic equipment.
7. Dependent on the battery voltage, the question "BEFORE CHARGE" or "AFTER CHARGE" will be displayed.
   - "BEFORE CHARGE" must be selected if the battery has not yet been charged.
   - "AFTER CHARGE" must be selected after the battery has been charged.
8. After testing, use the Midtronics printer to print a result ticket with the warranty code. The following tester results are possible:
   a. "CHARGE & RETEST" - If the battery has less than approximately 8 volts when tested and the tester does not find the battery to be defective (e.g., a shorted cell), the battery will be tested and the message "CHARGE & RETEST" will be displayed.
   b. "GOOD--RECHARGE" - If the tester displays "GOOD--RECHARGE", the battery must be retested after recharging.

Note: Should the tester display "GOOD--RECHARGE" after fully charging, print a second result ticket and charge the battery for two additional hours. If the tester still displays "GOOD-- RECHARGE", print the results and replace the battery.

   c. "GOOD BATTERY" - Only release the vehicle when the tester displays "GOOD BATTERY" and the open circuit voltage (OCV) is 12.6 volts or higher – this indicates a fully charged battery. Note that the display "GOOD BATTERY" is not in itself an indication of a fully charged battery. This is important, as the Midtronics tester does not require a 100% state of charge to determine whether the battery is good; however, a 100% state of charge is necessary to insure proper and trouble-free operation of the vehicle's electrical system components.
   d. "REPLACE BATTERY" - If the tester determines the battery to be defective, the message "REPLACE BATTERY" will be displayed.

9. Retain all Midtronics printouts with the warranty code in the vehicle file.

Additional Information

1. Below is an Open Circuit Voltage chart listing battery voltage as it relates to the state of battery charge.

   An Open Circuit Voltage measurement is only valid if the surface charge has been removed. It can be measured using a multimeter. It is also the voltage shown on the Midtronics printout. To remove the surface charge, turn on the high beams for one minute and then allow the battery voltage to stabilize (approximately one minute) before testing.

Open Circuit Voltage vs. State of Battery Charge

OCV	State of Charge
12.65 volts	100%
12.45 volts	75%
12.24 volts	50%
12.06 volts	25%
11.89 volts	Discharged

2. If the Midtronics tester detects a surface charge, it will be displayed on the tester. Follow the prompts to turn on the headlights for about one minute, and then follow the prompts. The tester will continue testing the battery automatically. For best results when testing the battery out of the vehicle, always remove the surface charge before testing if the battery has been charged.
3. Do not replace a battery just because the eye is black. The green eye is only an indicator of the cell to which it is attached.
4. When a discharged battery is encountered, check the function of the charging system. Perform the "Energy Diagnostics" test plan (B61 13 05) and, if necessary, check the electrical system for closed circuit current draw as per SI B61 08 00.
5. Other related Service Information bulletins:
   - SI B04 25 02 – Operation of current Midtronics tester
   - SI B04 11 02 - Operation of Deutronic DBL-430 charger

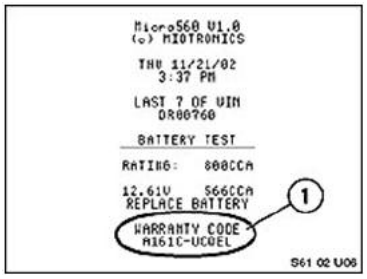
Note: For all models up to F10, we should use the Midtronics tester, NOT a VAT40 or equivalent. For F10 and later vehicles, a battery test is built into the vehicle (through the IBS), and is accessed using ISTA.

Note: A battery may only be replaced on F10 when identified as faulty using ISTA (the test plan returns a Diagnosis Code for the replacement)

Warranty Information

Warranty Code for claims relating to all BMW batteries

The warranty code is an encrypted code that includes all of the information from the printout.



Excluding the situation described in Note 2 (below), the Midtronics tester must be used for testing batteries with charge related defects, and that are to be claimed under warranty.

On completion of a battery test, print out the results, and file the printout with the completed repair order for future reference, if requested.

The printout contains a warranty code (1). This code must be included in the "Comments" section when submitting the warranty claim.

Failure to quote the warranty code in the comments of the warranty claim may result in a delay in processing or refusal of the warranty claim.

Notes :

1. **The "Warranty Code" is not an authorization number to replace the battery. Only replace the battery when this is stated in the test results (for example, "Replace Battery") or in the special case identified in 8b), above.**

2. **For vehicles with power management systems (vehicles with an IBS [Intelligent Battery Sensor]): If the battery is damaged due to discharge prior to QC1, depending on the vehicle model, either the message "Battery damaged, replace battery before delivery" will show during CBS Handover Inspection, or a similarly worded Check Control message will be displayed in the instrument cluster. In this case, a Midtronics printout is not required because the CBS message will be transmitted automatically within the FASTA data.**

3 **Battery failures that are the result of storage neglect or physical damage will not be covered by the BMW New Vehicle Limited Warranty.**

Closed Circuit Current Draw Testing

Increased closed-circuit currents may occur permanently or intermittently and cause the battery to discharge prematurely. The increase in closed circuit current may be caused by a faulty control unit or by the installation of a non-approved accessory.

Minimal amounts of parasitic draw can be overcome by the chemical reaction that takes place inside the battery. A problem occurs when the average vehicle current consumption higher that the battery can produce chemically.

In a situation where a vehicle has broken down due to a discharged battery, for diagnostic purposes it is important not to disconnect the battery. This is because a control unit will be reset if the battery is disconnected. Following a reset, the faulty control unit may start functioning correctly again, making accurate diagnosis impossible.

To correctly measure closed-circuit current, the 50-amp clip-on probe (previously used with the MIB) can now be used in conjunction with the IMIB (Integrated Measurement Interface Box) to properly diagnosis closed-circuit current problems over an extended period of time. Connect the 50-amp clip-on probe directly to the IMIB Measurement input 3 (green socket). Refer to SI B04 35 09 for information about the IMIB.

Use the following path to access this information:

- All except E65 and E66: Function structure>Body>Power supply>Deactivation, closed circuit current violation
- E65 and E66: Function structure>Body>Power supply>Voltage and current monitoring>Closed-circuit current performance>Closed-circuit current diagnosis.

The following tools are needed:

- ISID
- IMIB
- 50-amp clip-on probe

Performing a Closed Current Measurement

- It is very important that any "Power management" faults stored be diagnosed and corrected, and the "Energy Diagnosis" test plan carried out before the following procedure is performed.
- Check and test the battery using the BMW Battery Tester. Refer to SI B 04 25 02 for information about the BMW Battery. If necessary, recharge or replace the battery.
- If the battery is installed in the trunk, open the trunk and turn the lock to the locked position, using a screwdriver or similar (simulates the trunk lid being closed). The hood must be closed. If the battery is installed in the engine compartment, open the hood and pull the front lid contact switch fully up, and lock in this position (workshop position, simulates the front lid being closed). The trunk must be closed.

- With the exception of the trunk/hood above, all other doors/lids must be closed.
- In order to simulate normal closed-circuit conditions:
  - Turn the ignition on and activate all electrical consumers, including any accessories. Turn the ignition off. In some cases, a drive cycle may need to be carried out in order to duplicate a closed-circuit current problem.
  - Open and close the driver's door (simulates somebody getting out).
  - Lock the car, arming the DWA if this is installed.
- In general, closed-circuit current consistently over 50mA must be investigated. Depending on the vehicle's equipment, closed-circuit current by vehicle model is approximately as follows:

Vehicle	Closed circuit current measurement
E36, Z3	30 milliamps after 16 minutes
E46	40 milliamps after 16 minutes
E60, E61, E63, E64	40 milliamps after 60-70 minutes
E65, E66	40 milliamps after 60-70 minutes
E53	40 milliamps after 16 minutes
E70, E71, E72	40 milliamps after 60-70 minutes with TCU (30 minutes without TCU)
E83	40 milliamps after 16 minutes
E82, E88	40 milliamps after 60-70 minutes with TCU (30 minutes without TCU)
E90, E91, E92, E93	40 milliamps after 60-70 minutes with TCU (30 minutes without TCU)
E85	40 milliamps after 16 minutes
E89	40 milliamps after 60-70 minutes with TCU (30 minutes without TCU)
E52	50 milliamps after 16 minutes
F01, F02, F07, F10	7-21 milliamps after 30 minutes

- If the nominal milliamp reading is not achieved after the appropriate time, refer to the attached troubleshooting charts. On 2005 MY vehicles equipped with BMW ASSIST, there are additional current fluctuations as high as 500ma that last for approximately 2 minutes. The fluctuations occur every 15 minutes for up to 14 hours after key off. This is considered normal operation of the TCU, and should not be considered a fault. This also applies to 2005 TCUs that are installed into earlier production vehicles as replacement parts.

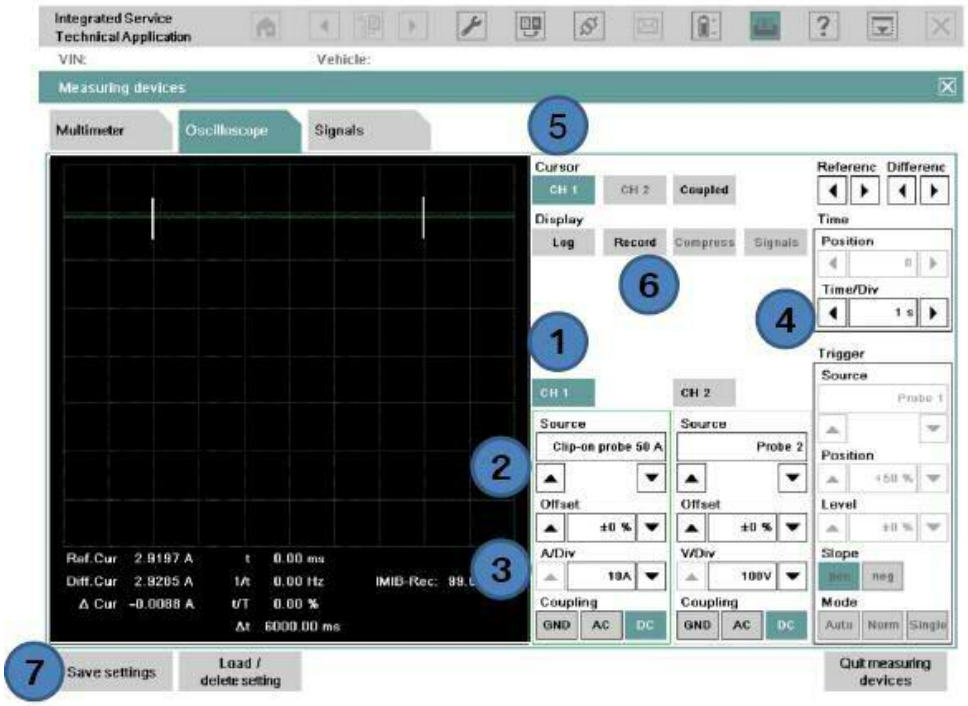
Closed Circuit Current Measurment with the IMIB

This technique with an IMIB is particularly suitable for extended measurements, and provides a graphical readout of recorded measurements over time. It is recommended for situations where the use of a multimeter provided insufficient information for problem diagnosis.

1. The IMIB can be accessed from any ISID within the workshop.
2. Select "Activities".
3. Select "Measuring devices".
4. Select from the "Level 1" column, "Measuring devices", and then "OK".
5. From the "Connection manager" screen, select the free IMIB and "Set up connection".
6. The "Measures devices" screen opens on the "Multimeter" tab.
7. Select the "Oscilloscope" tab.
8. Highlight the "CH1" tab to activate channel 1.
9. Under channel 1, "Source", scroll with the arrows to select "Clip-on probe 50A".
10. Make sure that clip-on probe is not connected to the battery cable, and acknowledge the pop-up message with "OK".
11. Change the "A/Div" setting to "1A".
12. Under the "Time" selection box, change the "Time/Div" setting based on the number of measurements needed (5 ms to 200 s). The longer times should be selected when performing the measurement over an extended period.
13. Select "CH 1" under "Cursor" to monitor the actual readings.
14. Select "Record" if performing long term measurements.
15. After performing the measurement, select "Record" again; the display will change to "Compress" and display the recorded data on the 1 screen.

Note: For further information regarding Closed-circuit Current Measurement refer to SI B61 08 00 available in ISTA.

Closed circuit current monitoring using the IMIB and the “Clip-on Clip probe 50A or 100A”



(1) Select channel 1 or 2.

(2) Change the “Source” to “Clip-on probe 50A or 100A” (confirm calibration prompt).

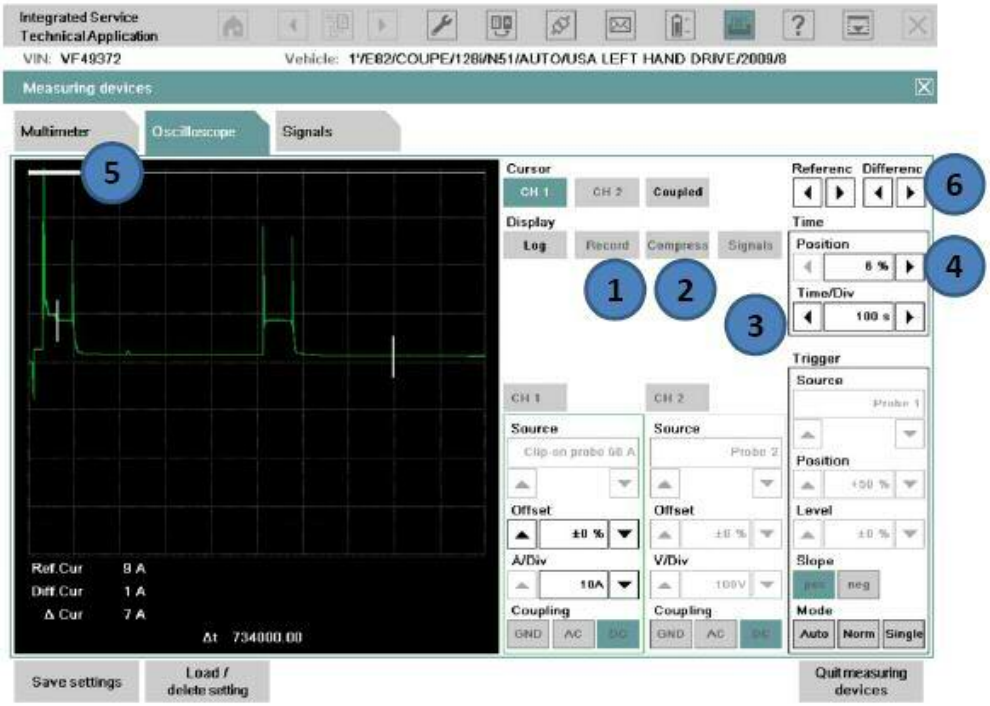
(3) Set “A/DIV” to “10A”.

(4) Change the “Time/DIV” in the “Time” box to “1 s” to start (the value can be changed if longer recording time is needed).

(5) Select the “Cursor” for the channel selected, 1 or 2.

(6) Once the measurement is started, press the “Record” button to start monitoring.

(7) Select “Save settings” to save the configuration setup (can be loaded back up at a later time).



(1) Select the “Record” button to stop recording.

(2) Select the “Compress” button to start analyzing the recorded signal.

(3) Change the “Time/DIV” in the “Time” box to the value which makes the signal easier to view glitches.

(4) Change the “Position” in the “Time” box to scroll through the signal.

(5) The white bar along the top of the display indicates the part of the entire signal being viewed.

(6) The cursor(s) may be moved to display the value of different parts of the display.

NOTES PAGE